Spatial Analysis of Asthma Prevalence and Exacerbation in Utah In Relation to Key Risk factors and with Particular Reference to Mining Activities

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Introduction
Mining is significant to Utah’s economy. In 2009, UT was the 3rd largest producer of non-fuel minerals, accounting for 7% of national production (Bon and Krahulec, 2009). Vowles et al. (2020) investigated county level (n=23) Adult Asthma Prevalence (AAP) and Asthma Emergency Room visits (AER). They found atmospheric pollution by small particulate matter ($PM_{2.5}$), which is known to cause respiratory problems, was greatest in the densely populated north of the state, but AAP and AER were only moderate. They found that the counties with the highest rates of AAP and AER in Utah were arid, had lots of mines and were economically disadvantaged. This sparked our interest in examining newly available AAP, AER and Asthma Hospitalization [AHOS] data for Utah Small Areas (n=89) in relation to a range of risk factors and mining activities. In particular, researchers in Iran showed elevated Zn and Pb concentrations in topsoil and dust samples within 5 km of a Zn and Pb mine (Molokht et al. 2018). Research in Chile found a considerably increased risk of respiratory diseases closer to mines, that became negligible at a minimum distance of 1.3 km (Herrera et al. 2016). The research concluded that airborne particles related to industrial gold or copper mines enhanced children’s risk of respiratory diseases. Utah ranks second in the U.S. in the historical production of copper and silver; third in the lead, fifth in gold, and ninth in zinc (Krahulec, 2019). This means Utahans who live close to mines could be prone to respiratory diseases.

Methods
Data for this research were collected from a range of sources IBIS-PU, Utah AGRIC, HealthData.gov, United States Geological Survey (USGS) and the Utah State Board of Labor Statistics (Tables 1 and 2). The hypothesized relationship (+) between each variable and asthma outcomes based on literature review is given in Tables 1 and 2. Some variables were downloaded and used in their original form whereas others were pre-processed before use. Average elevation for Utah Small Areas was calculated from a 30m digital elevation model. Average distance to mines from cities, mine and road counts and densities were derived from mine locations in relation to Utah Small Area Boundaries in ArcGIS Pro and ArcMap. Seasonal means, minimums and maximums of $PM_{2.5}$ levels were calculated from the daily concentration (C) $PM_{2.5}$ estimations from the EPA downscaled model and were then aggregated to the Utah Small Areas.

AAP, AER and AHOS rates were divided into 2 or 3 groups representing high and low, or medium and low asthma rates based on the histograms of these variables. The resulting groups were used for non-parametric Kruskal Wallis H and Mann Whitney U comparison tests (Tables 1 and 2) to determine if there are significant differences in the asthma risk factor variables for locations with high, medium and low asthma rates. Pearson’s correlations were used to measure the relationships between AAP, AER and AHOS and the risk factor variables. Multiple linear and spatial regression analysis was used to determine the most important covariates for AAP, AER and AHOS, the dependent variables (Tables 1 and 2), while examining all appropriate diagnostic checks related to data distribution and avoiding multi-collinearity issues. Univariate local Moran’s I analysis was used to determine the location of significant clusters of high AAP, AER and AHOS rates and bi-variate analysis was used to identify co-located clusters of key risk factors.

Table 1: Kruskal Wallis H, Whitney U test, Pearson’s correlation and multiple linear and spatial regression results

Table 2: Kruskal Wallis H, Whitney U test, Pearson’s correlation and multiple linear and spatial regression results continued

Results and Discussion
Figure 1 shows quartile maps of AAP, AER and AHOS. AAP rates are highest in northern and central areas, for AER and AHOS, rates are highest in northern and central Utah (Figure 2). Figure 2 shows univariate maps cluster maps for AAP, AER and AHOS. For AAP (Figure 2a), the pink areas (high AAP surrounded by low AAP) in central Utah contain many mines. For AER (Figure 2b) and AHOS (Figure 2c), the red and blue clusters of high AER or AHOS rates are close to the Bingham Canyon Copper Mine which is one of the largest open-pit mines in the world.

Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>AAP</th>
<th>AER</th>
<th>AHOS</th>
</tr>
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<tbody>
<tr>
<td>Zn Mine</td>
<td>0.229</td>
<td>0.049</td>
<td>0.229</td>
</tr>
<tr>
<td>Pb Mine</td>
<td>0.175</td>
<td>0.344</td>
<td>0.314</td>
</tr>
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| Economic Characteristics of Counties with a High Asthma Burden to Focus on: (a) AAP and Hit Index (b) AAP and Unpaved Road Count (c) AAP and Smoking Rate (d) AHOS and Annual Mine Work Hours

Figure 1. Asthma Rate Maps for Utah Small Areas (n=99) for:
(a) AAP
(b) AER
(c) AHOS

Figure 2. Univariate Local Moran’s I Maps for Utah Small Areas (n=99) for:
(a) AAP
(b) AER
(c) AHOS

Figure 3. Bi-variate Local Moran’s I Maps for Utah Small Areas (n=99) for:
(a) AAP and Hit Index
(b) AAP and Unpaved Road Count
(c) AAP and Smoking Rate
(d) AHOS and Annual Mine Work Hours

Conclusions
Due to the ecological fallacy that occurs when using population level data, we cannot make conclusions about the individuals suffering from asthma, only the characteristics of the small areas that have the highest rates and where there are spatial clusters. The results show that AAP, AER and AHOS are more strongly related to climatic risk factors, socio-economic status and mining activities. This research suggests that levels of toxic particulates in the atmosphere around mines, especially in arid areas should be further investigated and that these small areas should become the focus of individual level studies. Also, policies that could address socio-economic disparities within the state, particularly in relation to health insurance and educate regarding behavioral risk factors for asthma could potentially ease pressure on already taxed emergency departments and hospitals.

References